COMMONWEALTH OF KENTUCKY
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
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April 9, 1975

MEMO TO: J. R. Harbison
State Highway Engineer

SUBJECT: Research Report No. 425; "Evaluation of Raised Pavement Markers;" KYP-73-48; HPR-PL-1(10), Part III.

The report submitted herewith is a sequel to No. 384 ("Raised Pavement Markers as a Traffic Control Measure at Lane Drops"). Report 425 is the implementation package for more extensive installations of raised markers already planned and awaiting contract. These pending projects will be the first, major use of this type of line marker in Kentucky. The construction detour at the I 75 - I 275 interchange in northern Kentucky has been delineated with these markers. They have been used on the concrete median barrier at Covington and southward. Other trial installations have been made by Research. The observations and overviews reported and the layouts and specifications included were coordinated with the Traffic Division and generally incorporated into the plans. The projects now pending comprise a state, pilot program which is not directly related to the Pavement Marking Demonstration Program authorized in the Federal Aid Highway Act of 1973.

This report does not address the comparative economics of pavement marking systems nor the eventual role of raised markers in striping and marking practices. However, public appreciation for the exceptionally bright delineation -- especially during rainy, nighttime conditions -- on the pilot projects is expected to be very high.

Other projects, not necessarily or solely involving raised markers, will be forthcoming as part of the federal Pavement Marking Demonstration Program.

Additional photos, some of which may be of historical interest, are attached (ahead of the report).

Respectfully submitted,

Jas. H. Havens
Director of Research

JHH:gd
Attachment
CC's: Research Committee

Photo 1: Steel, Button-Type, Raised Marker at a Street Crosswalk in Lexington (Upper and Short Streets). Markers of this type originated in the early 1920's and were made of brass.

Photo 2: Raised, Plastic Markers (Dur-O-Line) Installed on Main Street in Lexington in 1950. They were glued and nailed to the pavement. They did not prove to be durable.

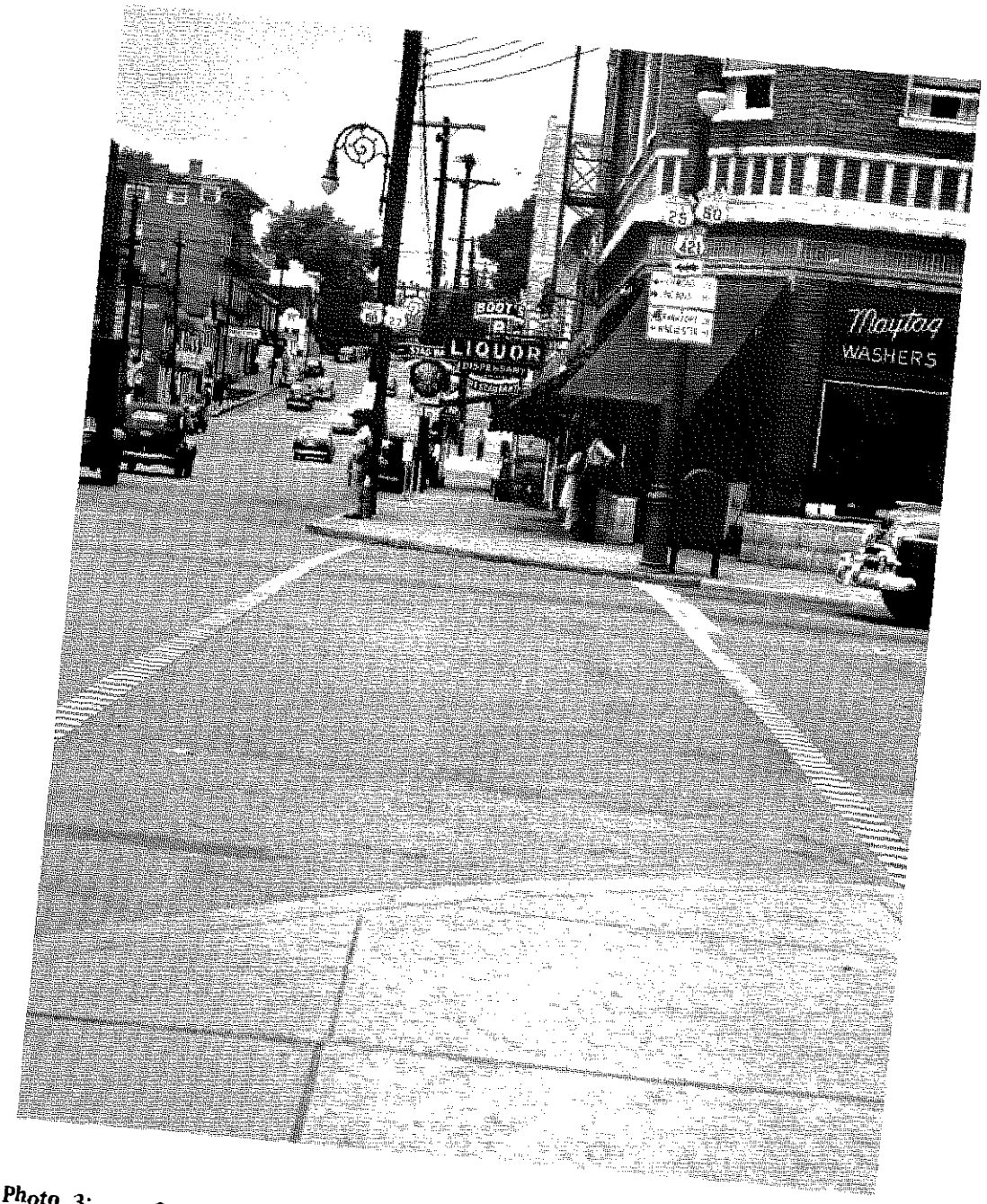

Photo 3: Crosswalks Markers; Lexington; 1950. Markers of this type were known at one time as Linoleum Blocks; some had a mastic adhesive; and some were reflectorized with glass beads.

Photo 4: A Rainy Nighttime View of Grooved-and-Painted Centerline. Alternate skip-stripes were grooved to improve drainage from the beaded paint and to minimize loss of reflectivity (Research Reports 282, October 1969, and 314, October 1971).

Photo 5: Twilight View of I 75 - I 64 (Northbound) Lane Split after Installation of Reflective, Raised Markers (4-1-75). Earlier, trial installation at this site was damaged by snowplows; markers were restored prior to photographing.

TECHNICAL REPORT STANDARD TITLE PAGE

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Study Title: Evaluation and Application of Roadway Delineation Techniques

16. Abstract

The purpose of this study was to evaluate the operational applicability of raised pavement markers and to determine their effectiveness with respect to brightness and durability. Seven different types of markers were evaluated. The primary application of markers in this study was as a supplement to lane lines. They were also used as a traffic control measure at lane drops, as delineation for hazardous curves, and as directional arrows.

Luminosity and durability were monitored for approximately one year. It was found that raised pavement markers can be a very effective method of roadway delineation. Markers evaluated had varying levels of brightness and durability. Costs varied considerably among types.

Specifications, which classified and described the markers, were proposed. Details for the recommended design layout of markers as supplements to and replacements for lane lines were proposed.

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Research Report
425

EVALUATION OF RAISED PAVEMENT MARKERS

KYP-73-48, HPR-PL-1(10), Part III

by
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Bureau of Highways
DEPARTMENT OF TRANSPORTATION
Commonwealth of Kentucky

April 1975

SUMMARY

The purpose of this study was to evaluate the operational applicability of raised pavement markers and to determine their effectiveness with respect to brightness and durability. The markers evaluated were Stimsonite 88, Permark (P-15), Safety Guide, Ray-O-Lite (regular lens), Ray-O-Lite (replaceable lens), Little Jewel, and 3M's PD-50. They were evaluated primarily as a supplement to lane lines but were also used as a traffic control measure at lane drops, as delineation for hazardous curves, and as directional arrows.

Luminosity measurements in the field were accomplished using a specially constructed photometer; reflectivity measurements were obtained with the ESNA Reflex - Photometer in the laboratory. The Stimsonite and Ray-O-Lite (regular) markers were the brightest; the Permark, Safety Guide, and Little Jewel markers were found to be considerably less bright. The 3M marker was very bright initially, but the brightness level was not maintained. The Permark marker was rated best for daytime visibility; the Safety Guide and Little Jewel markers were rated only slightly lower. Ray-O-Lite markers had limited daytime visibility; Stimsonite and 3M markers had practically no daytime visibility.

Field observations were made over a period of approximately one year to determine the durability of the markers and the number of markers damaged or missing. When used as supplements to lane lines, the 3M marker had the highest percentage loss. The Ray-O-Lite (replaceable lens) also had a substantial percentage loss. Stimsonite, Ray-O-Lite (regular), Permark, Safety Guide, and Little Jewel appeared to have sufficient durability in the test installations. A substantial loss of markers was attributed to snowplowing and some due to vandalism. In addition to the markers which were displaced from the pavement several markers also showed chipped lenses or bodies.

The cost of the raised markers ranged from $0.22 each for the Permark non-reflective type to $1.20 each for the Stimsonite and Ray-O-Lite bi-directional types. Installation costs also varied considerably depending upon the specific location.

Specifications were prepared, and the markers were classified as follows:

Type I	Non-reflectorized marker,
Type II	Reflectorized marker, and
Type III	Highly reflectorized marker.

Details for the recommended uses of raised markers as supplements to and replacements for lane lines are given.

INTRODUCTION

Raised markers on pavements have increased in use in the last several years as a part of the roadway delineation system. These markers have proven to be especially effective for wet nighttime and other poor visibility conditions when beaded paints are usually least effective. They have also become popular where traffic is intense and where frequent repainting of lane lines is necessary and poses a hazard to painting crews. They are also being used to delineate horizontal curves, merge and diverge areas, turning lanes, no-passing zones, and stop approaches *(1)*. A previous study conducted by the Division of Research showed that raised markers are an effective means of reducing erratic movements at lane-drop locations *(2)*.

The use of these markers has increased most rapidly in southern states where snowfall is minimal and snowplows are not needed. Damage from steel snowplow blades has been a major deterrent to their application in snow areas. Considerable work has been done to develop snowplowable markers. The Federal Highway Administration has requested states in areas where snowfall is common to review their snowplowing and de-icing procedures and to consider the use of de-icers and rubber snowplow blades in order to utilize raised markers *(3)*. A study conducted by the state of Washington demonstrated that rubber-tipped snowplow blades were effective for removing freshly fallen or slushy snows and did not damage raised markers *(4)*.

Several different types and brands of raised markers have been developed and used. The markers vary in cost, durability, and brightness. In this study, seven different markers were evaluated.

PROCEDURE

INSTALLATION

The raised markers (Figure 1) evaluated in this study are listed below:

1. Stimsonite 88 (Amerace Corporation),
2. Permark (P-15) (Ferro Corporation),
3. Safety Guide (International Plastics, Incorporated),
4. Ray-O-Lite (regular) (Ray-O-Lite, Incorporated),
5. Ray-O-Lite (replaceable lens) (Ray-O-Lite, Incorporated),
6. Little Jewel (Roadways International Corporation), and
7. PD-50 Rubber Delineator (3M Company).

The markers were installed at several situational locations. The major installations were as supplements to lane lines. They were also used as a traffic control measure at lane drops, as delineation for hazardous curves, and as directional arrows. Detailed information on the type and number of markers used at each location is given in APPENDIX A.

The markers were applied using a two-part epoxy adhesive. Surfaces were prepared by sandblasting or scrubbing with a wire brush prior to application of the epoxy. Traffic was maintained during application, but traffic cones were used to prevent vehicles from crossing the markers until the adhesive hardened.

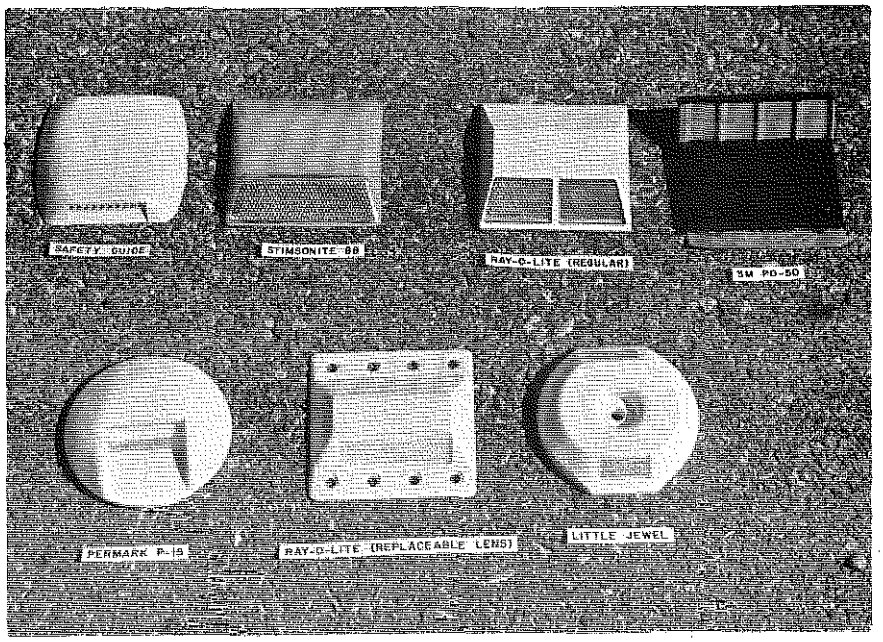


Figure 1.
Types of Raised Pavement Markers Evaluated.

DATA COLLECTION

Nighttime field testing of luminosity was accomplished with a specially constructed photometer, similar to a device developed by Colorado *(5)*. Major components of the photometer are a sealed-beam spotlight, lens and photocell assembly, and a transistor amplifier. Output from the photometer was recorded on a strip chart. The spotlight and detector were mounted on a vehicle as shown in Figure 2. The photometer was aimed to a point on the pavement 10 feet (3 meters) in front of the vehicle. Measurements were taken at night by driving the vehicle slowly along the roadway with the spotlight centered over the line of markers. Chart readings were later converted to equivalent luminance (foot-lamberts) (candela/square meter) through the calibration curves shown in Figure 3. The calibration curves were derived in the laboratory by relating the photometer output to the readings from a G.E. light meter (Type SL480A).

A modified ESNA Reflex-Photometer (Figure 4) *(6)* was used in the laboratory to determine the specific reflectivity of the markers. Selected samples of markers and photometric data were obtained from several manufacturers and compared to measurements with the ESNA Reflex-Photometer. Periodic field inspections were made to determine the durability of the markers and the number of markers damaged or missing.

RESULTS

BRIGHTNESS

Luminance of the markers was measured periodically at two locations. The results are shown in Figures 5 and 6. Brightness of a given marker type varied considerably throughout the study period; this variability was attributed to the amount of dirt accumulation on the faces of the lens systems. The brightness ranking of the markers, however, remained unchanged. The Stimsonite and Ray-O-Lite (regular) markers were the brightest, and the Ray-O-Lite (replaceable lens) marker was somewhat less bright. The 3M marker was reasonably bright initially; the reflective portion of the marker was soon worn by traffic. This decrease in brightness was most pronounced at the Limestone Street location where lane changes occurred frequently. The Permark, Safety Guide, and Little Jewel markers exhibited very similar brightness during the study period. Photographs of the installations are presented in APPENDIX B.

Visual observations were made during daylight to determine daytime visibility. The Permark marker was judged the best, and the Safety Guide and Little Jewel markers also had good daytime visibility. The Ray-O-Lite markers had limited daytime visibility; the Stimsonite and 3M markers had nominal visibility.

Results of laboratory tests for reflectivity are presented in Table 1. The ranking of markers according to these tests was similar to the ranking from field measurements. Based on brightness criterion, the markers grouped as follows: Stimsonite and Ray-O-Lite, brightest; Permark and Safety Guide, medium brightness; and 3M and Little Jewel, least bright.

DURABILITY

The durability of the markers, as shown in Figures 7 and 8, varied significantly. When used as supplements to lane lines (Figure 7), the 3M marker had the highest percent loss -- 67 percent after 310 days in service. The large loss was attributed to poor adhesion to the pavement. Part of that loss was attributed to vandalism inasmuch as the markers could be pulled from the pavement by hand. A new adhesive has since been developed for this marker, and three of the markers with the new adhesive have been in service for over seven months without loss. The Ray-O-Lite (replaceable lens) marker also had substantial percentage loss after one year in service (22 percent). The lens and body of this marker were not durable (Figure 9), and the company has since discontinued its production. The Stimsonite marker had an eight percent loss after a year. Many of these markers separated from the pavement along with fragments of the pavement surface. The Ray-O-Lite (regular) and Permark had a loss of only one marker; all of the Safety Guide and Little Jewel markers remained intact.

Several of the edgeline markers were installed in high-speed and high-traffic-volume areas which were also subjected to substantial snowplowing (Figure 8). The Stimsonite and Safety Guide marker installations were snowplowed. Excluding the markers lost by snowplowing, ten percent of the Stimsonite and about two percent of the Safety Guide markers were lost due to other causes. The Permark markers also received some snowplow damage, but a large number were lost due to other causes. Truck volume and high speed are believed to have generated impacts sufficient to break some markers (Figure 10); some failures were between the marker and adhesive (Figure 11). The 3M marker had a loss of 30 percent, and this area had not been snowplowed. This was a much smaller loss than at the lane line locations. Apparently fewer edgeline markers were impacted by traffic; and, apparently, fewer markers were otherwise lost or stolen. The Ray-O-Lite sites were also subjected to snowplowing; the Ray-O-Lite (replaceable lens) marker had a loss of 17.5 percent while the Ray-O-Lite (regular) markers had only a three-percent loss.

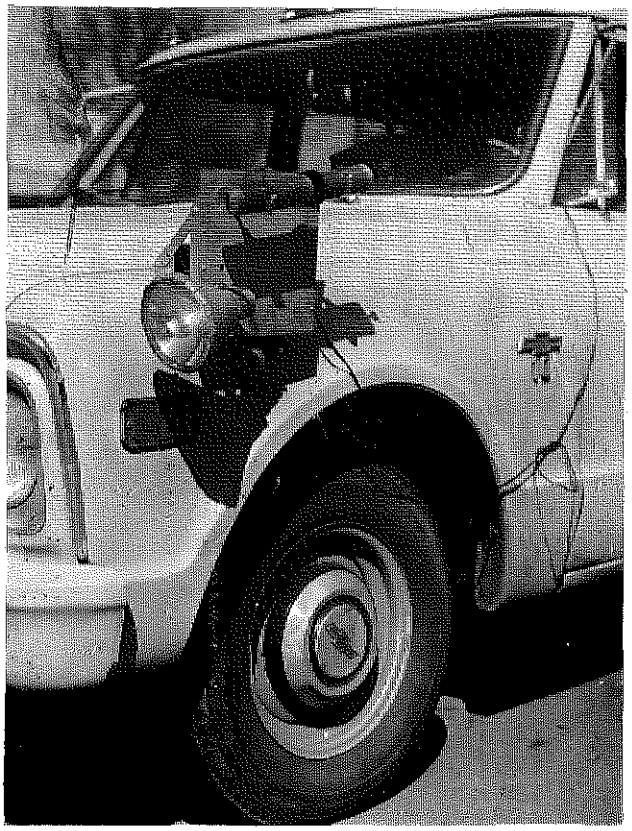


Figure 2.
Photocell Assembly and Spotlight Mounted on Vehicle.

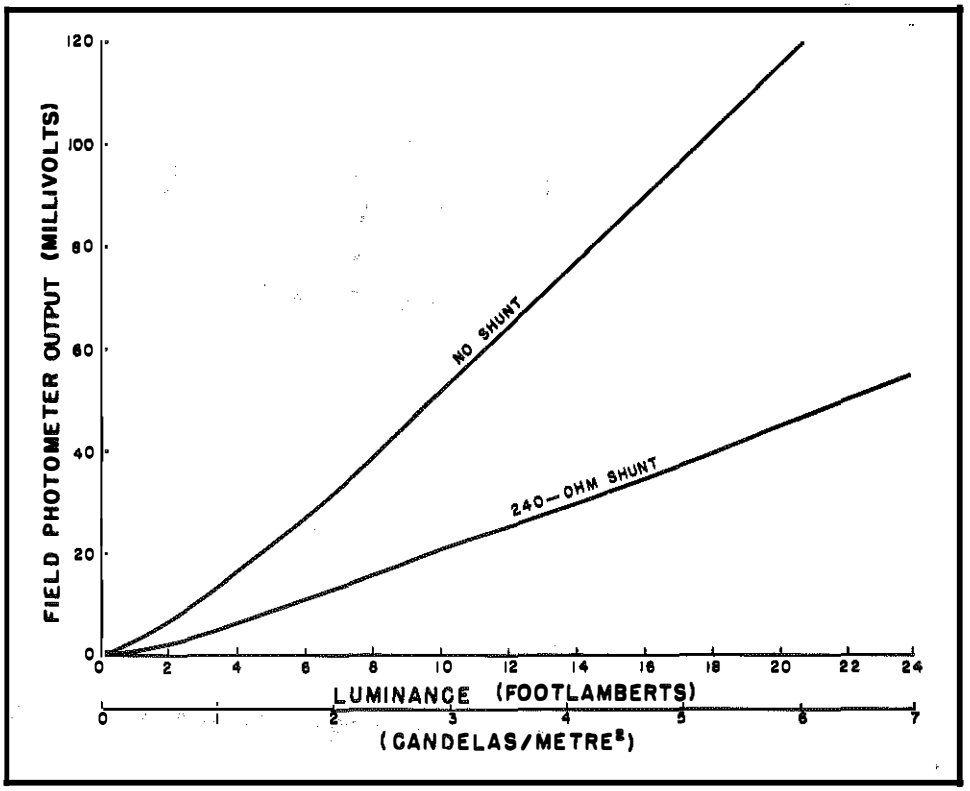


Figure 3. Calibration Curves for Field Photometer.

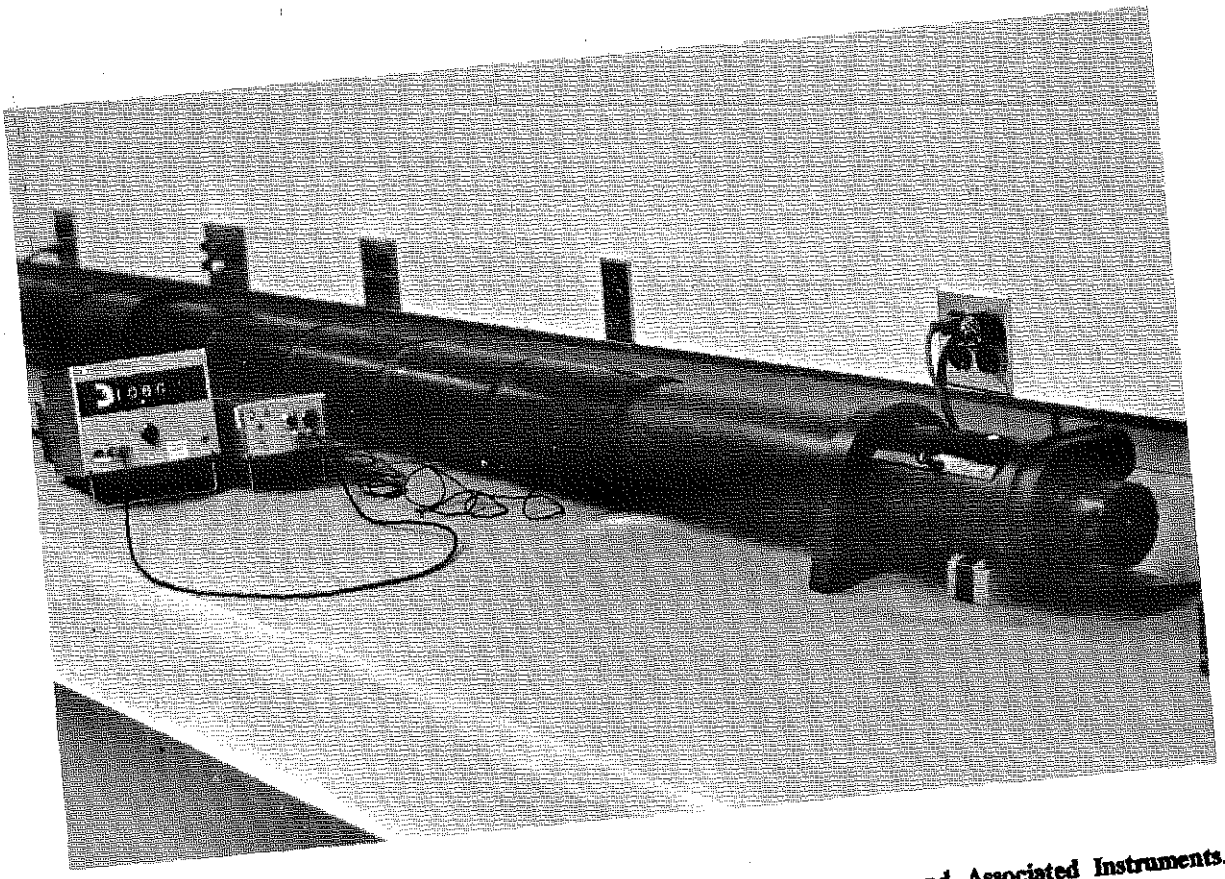
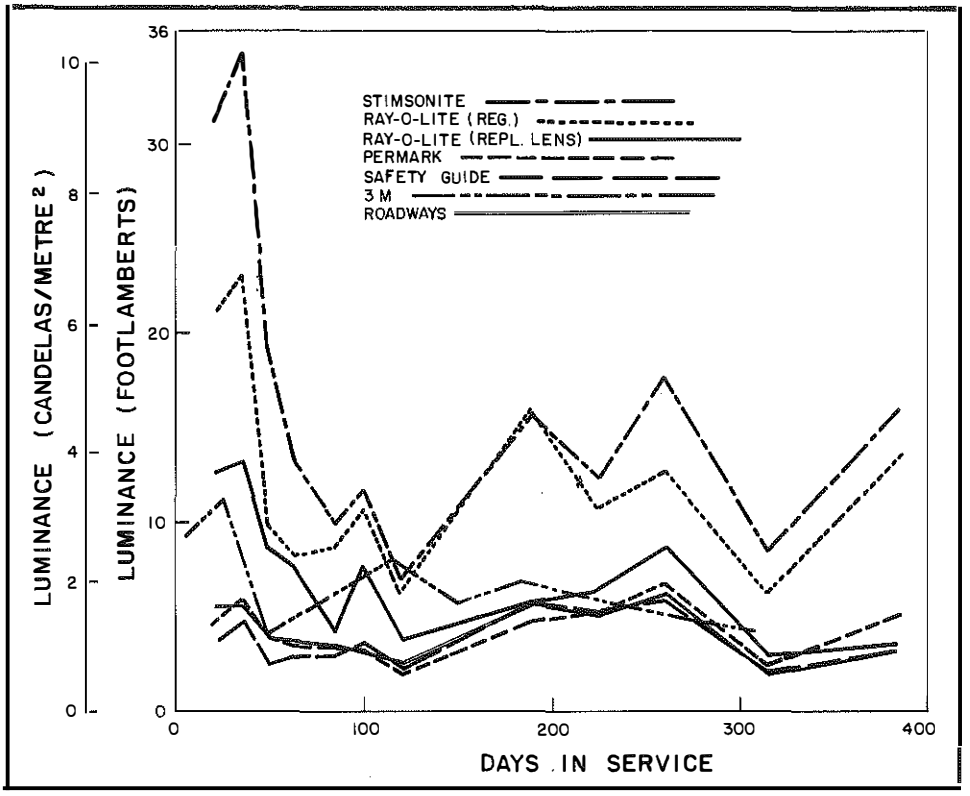


Figure 4. ESNA Reflex-Photometer and Associated Instruments.

Figure 5. Luminosity of Raised Markers at Fayette Mall in Lexington (Installed 7-25-73).



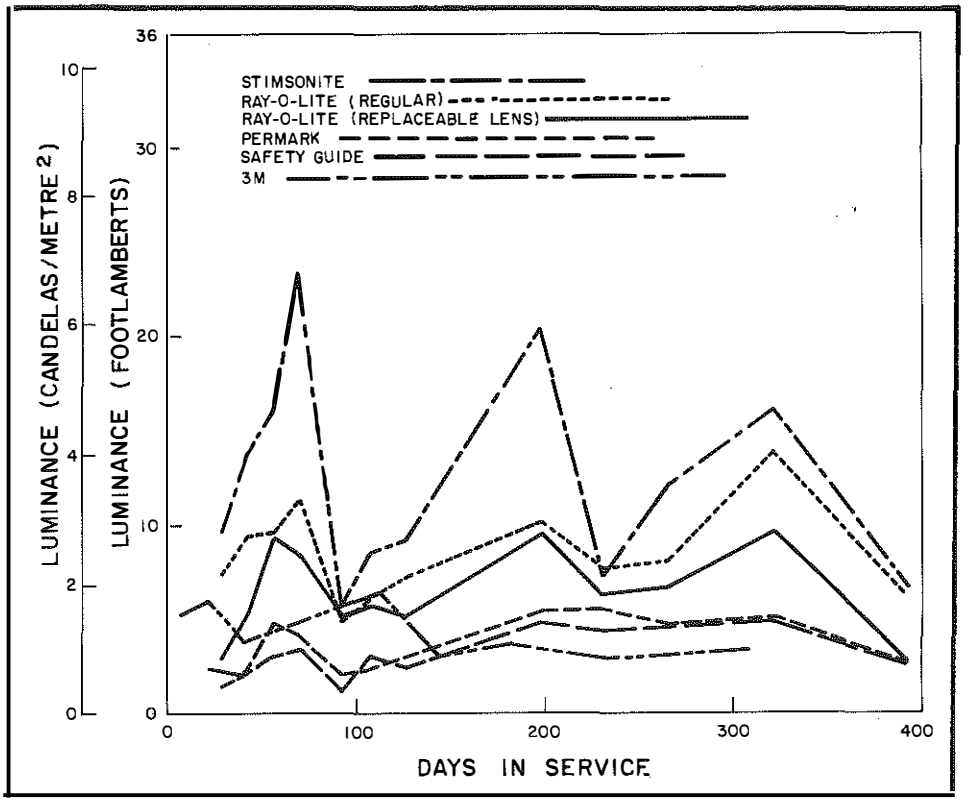


Figure 6. Luminosity of Raised Markers on South Limestone Street in Lexington (Installed 7-18-73).

TABLE 1. SPECIFIC REFLECTIVITY OF SELECTED RAISED PAVEMENT MARKERS

BRAND NAME	COLOR OF REFLECTIVE LENS SYSTEM	SPECIFIC REFLECTIVITY (0.2° DIVERGENCE ANGLE)	
		0° INCIDENCE ANGLE	20° INCIDENCE ANGLE
Stimsonite 88	Silver White	5.5	2.4
	Amber	3.1	1.4
	Red	1.4	0.7
Ray-O-Lite (Regular)	Silver White	3.0	1.6
	Amber	1.3	0.83
	Red	0.64	0.38
Permark P-15	Silver White	1.04	0.82
	Amber	0.60	0.45
	Red	0.17	0.13
Safety Guide	Silver White	0.68	0.40
	Red	0.06	0.02
PD-50 (3M)	Silver White	0.34	0.21
Little Jewel	Silver White	0.15	0.02
	Amber	0.14	0.01
	Red	0.06	0.01

Figure 7. Durability of Various Markers as Supplements to Lane Lines.

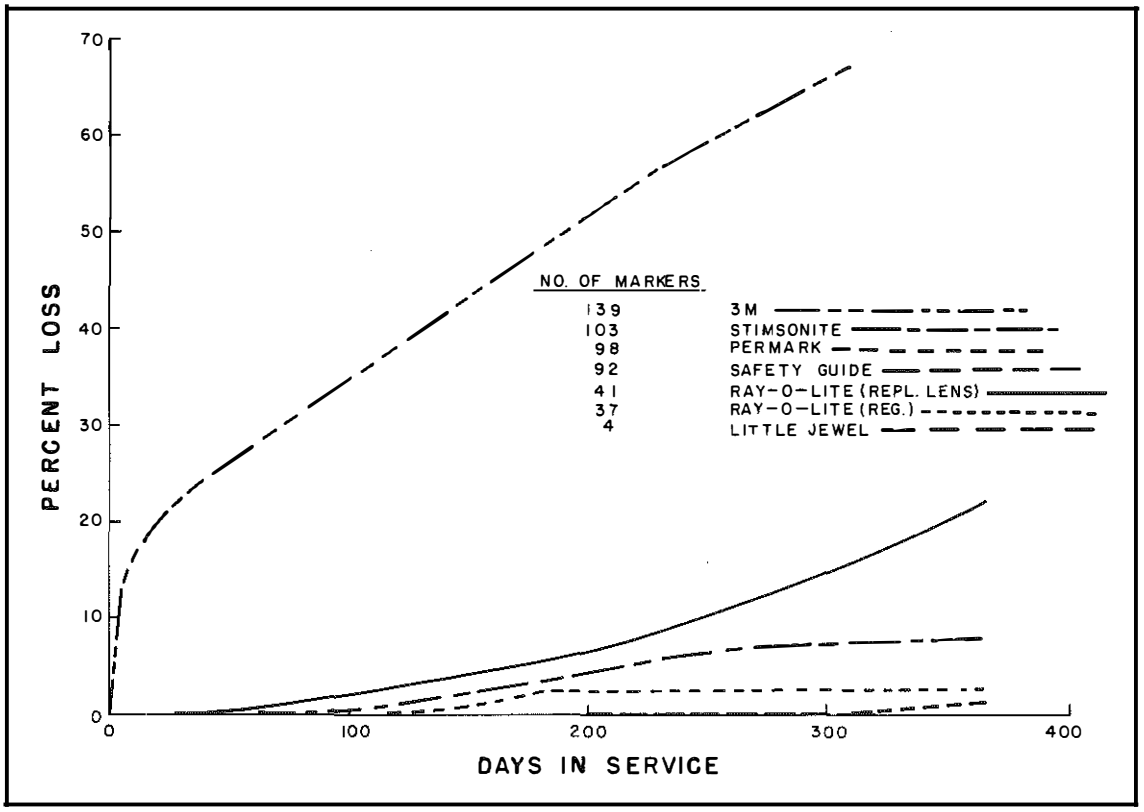
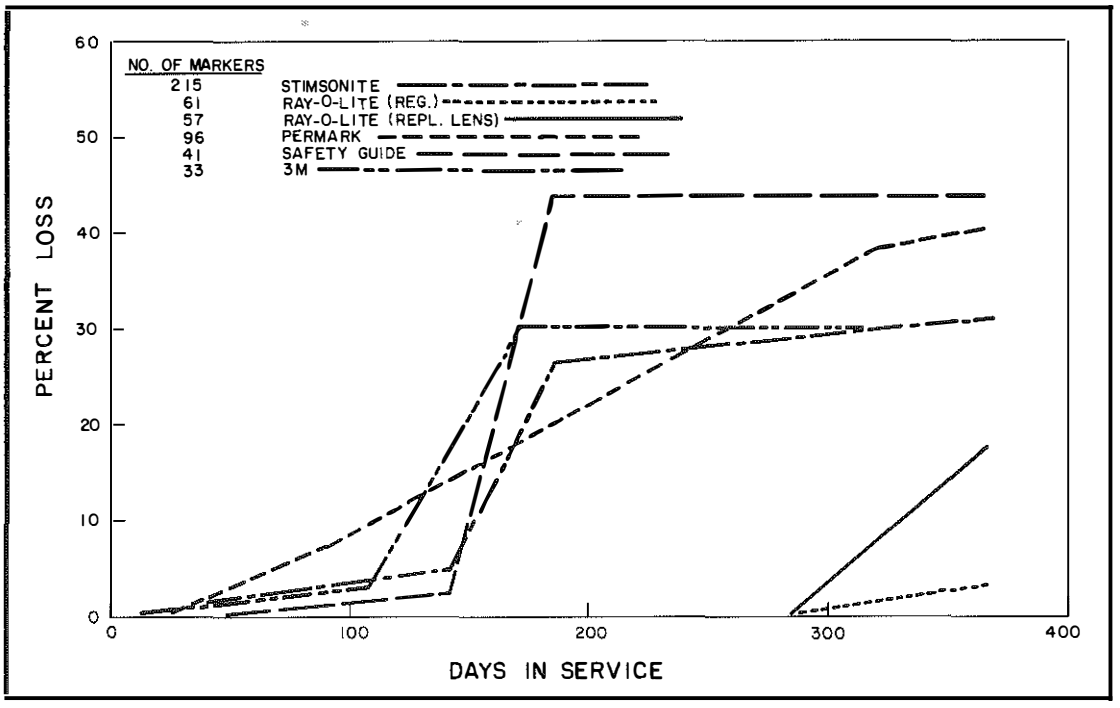


Figure 8. Durability of Various Markers as Edge Lines (Including Snowplow Damage).



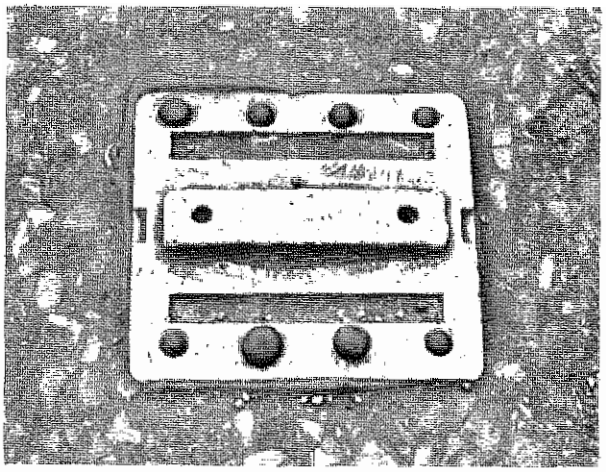


Figure 9. Damage to Ray-O-Lite (replaceable lens) Marker. Replaceable Lens Is Missing.

Figure 10. Damage to Permark Marker.

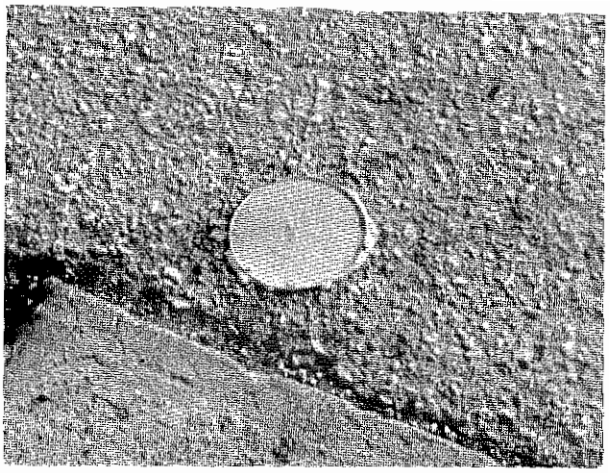


Figure 11. Loss of Adhesion between Permark Marker and Adhesive.

Markers which were removed by a snowplow demonstrated the strength of the bond between the epoxy and pavement. Although the snowplow removed nearly all the markers encountered, fragments of pavement often adhered to the marker. In a few cases, only the tops of the markers were sheared off.

In addition to the markers lost, several were damaged in varying degrees. The damage was usually chipping of either the lens or body. Table 2 summarizes the number and percentage of markers which were damaged. The Ray-O-Lite (replaceable lens) marker experienced the highest percent damaged. An additional problem with this marker was a darkening of the lens (Figure 12), which resulted in reduced brightness. The Stimsonite, Safety Guide, Permark, and Ray-O-Lite (regular) markers were similar in percent damage. Damage to the Stimsonite and Ray-O-Lite (regular) markers usually consisted of chipped lenses (Figures 13 and 14). The Safety Guide and Permark markers frequently became covered with dirt (Figures 15 and 16). A small number of 3M markers was damaged similarly to those shown in Figure 17. There was no damage to any of the small number of Little Jewel markers installed.

There were also six installations of directional arrows. Dimensions of the arrow were the same as shown in the Manual on Uniform Traffic Control Devices *(7)*. The configuration of markers is shown in Figure 18. Daytime and nighttime photographs of installations are shown in Figures 19 and 20. These installations appeared to be very effective, but there was a durability problem. Of the 134 markers installed, 67 (50 percent) were lost and 19 (14 percent) were damaged. The loss was largely attributable to snowplowing.

COST

The comparative costs of the various raised pavement markers are presented in Table 3. There is a wide range of costs, depending on type and quantity; however, it is a very important factor when alternative types of markers are being considered. A more detailed evaluation of the costs involved with various lane-line replacement schemes is dealt with in the next section of this report. A previous report *(2)* summarized the materials and installation costs for raised markers used as traffic control measures at lane drops.

DISCUSSION

SPECIFICATIONS

It was found that raised markers can be very effective for roadway delineation. The markers evaluated have varying levels of reflectivity, durability, and cost. Specifications are proposed; the markers are classified as follows:

Type I	Non-reflectorized marker,
Type II	Reflectorized marker, and
Type III	Highly reflectorized marker.

The proposed specifications are cited in APPENDIX C. The specifications include requirements for the material composition of the marker as well as reflectivity requirements.

LANE LINE REPLACEMENT

Raised markers have been used extensively in various states to replace other lane lines. Many designs have been used and careful consideration should be given to any design selected. The brightness and durability of the markers must be considered to assure that adequate nighttime visibility will be maintained. As previously stated, the various markers differ in brightness and durability.

The California marking system involved four, non-reflective, white markers spaced 3 feet (1 meter) apart to represent the stripe and followed by a 15-foot (5-meter) gap, as shown in Figure 21. A two-way, highly reflectorized marker is placed in the gap 48 feet (14 meters) apart on tangent and 24 feet (7 meters) apart on curved sections.

The Washington state standard for lane markers requires a set of six markers placed 3 feet (1 meter) apart and 25 feet (7 meters) between sets (Figure 22). The first marker in alternate sets (every 80 feet (24 meters)) is highly reflectorized. The exception is on horizontal curves with radii less than 5,000 feet (1525 meters) where the spacing between highly reflectorized markers is reduced to 40 feet (12 meters).

The Texas marking system involves six, non-reflectorized, white markers spaced 3 feet (1 meter) apart, representing the stripe, followed by a 25-foot (7-meter) gap (Figure 23). Highly reflectorized markers are placed in the gap on 80-foot (24-meter) centers. If the grade is greater than two percent, a 40-foot (12-meter) spacing may be used.

TABLE 2. DAMAGE TO RAISED PAVEMENT MARKERS

BRAND NAME	NUMBER INSTALLED	NUMBER DAMAGED	PERCENT DAMAGED
Stimsonite 88	363	47	12.9
Safety Guide	177	21	11.9
Permark P-15	194	24	12.4
Ray-O-Lite (Regular)	142	24	16.9
Ray-O-Lite (Replaceable Lens)	98	22	22.4
PD-50 (3M)	172	4	2.3
Little Jewel	4	0	0
Total	1150	142	12.3

Figure 12. Darkened Lens of Ray-O-Lite (replaceable lens) Markers.

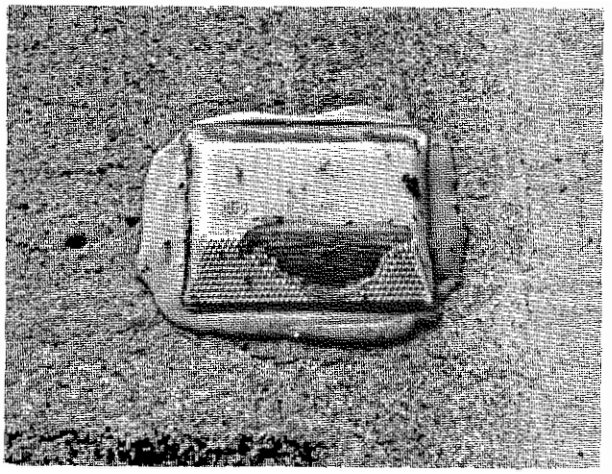


Figure 13. Damage to Stimsonite Marker.

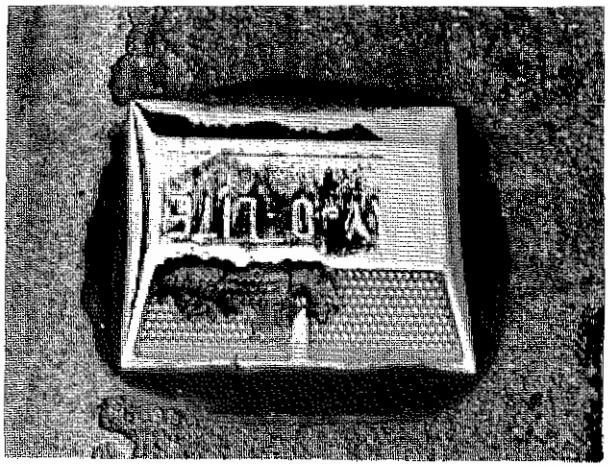


Figure 14. Damage to Ray-O-Lite (regular) Marker.

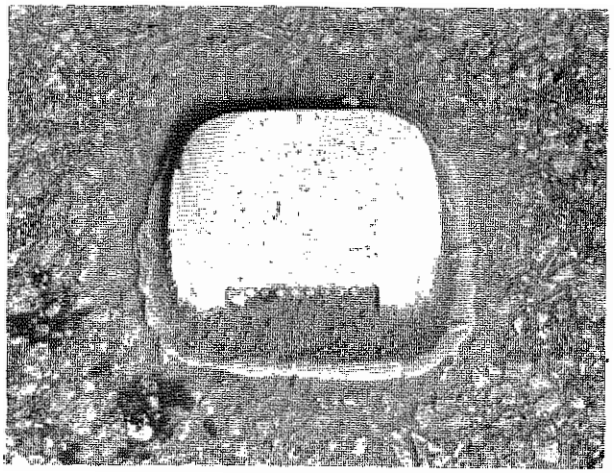


Figure 15. Dirt Covering Glass Beads of Safety Guide Marker.

Figure 16. Dirt Covering Reflective Lens System of Permark Marker.

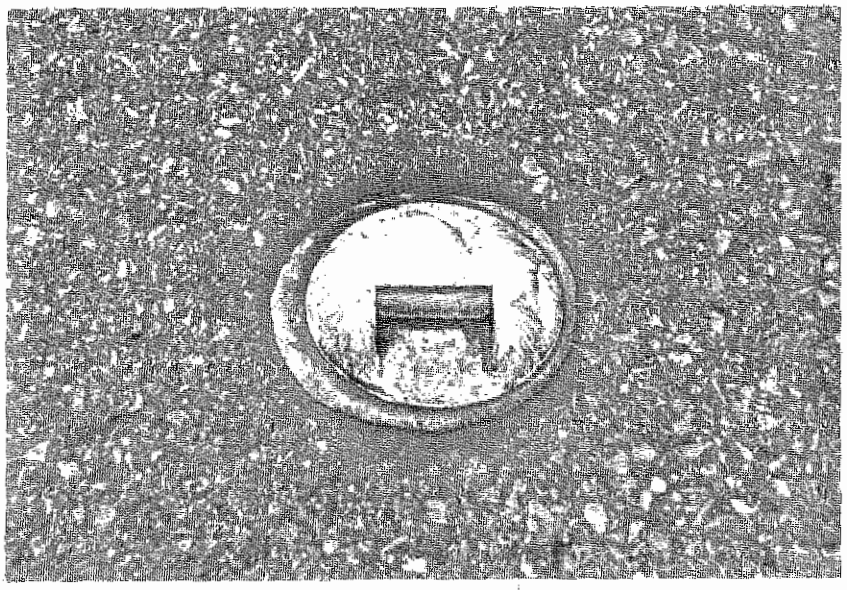
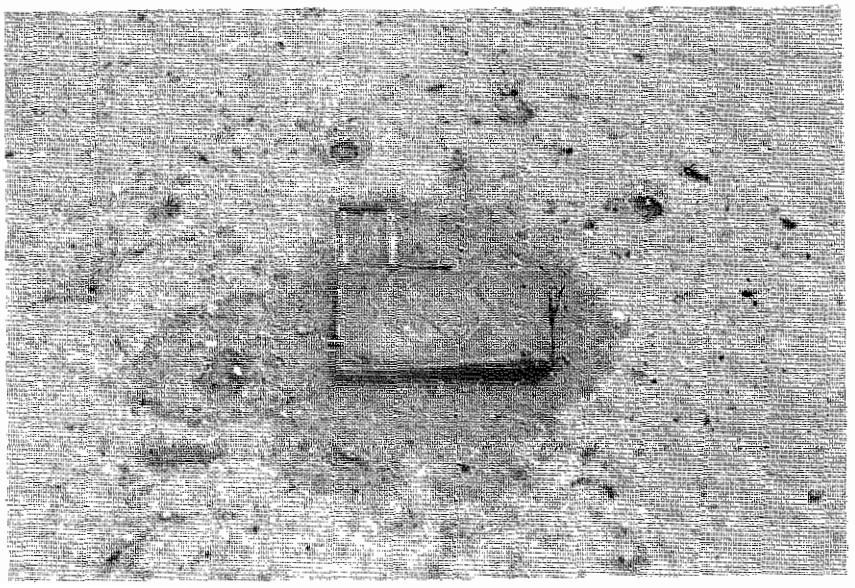


Figure 17. Damage to 3M Marker.



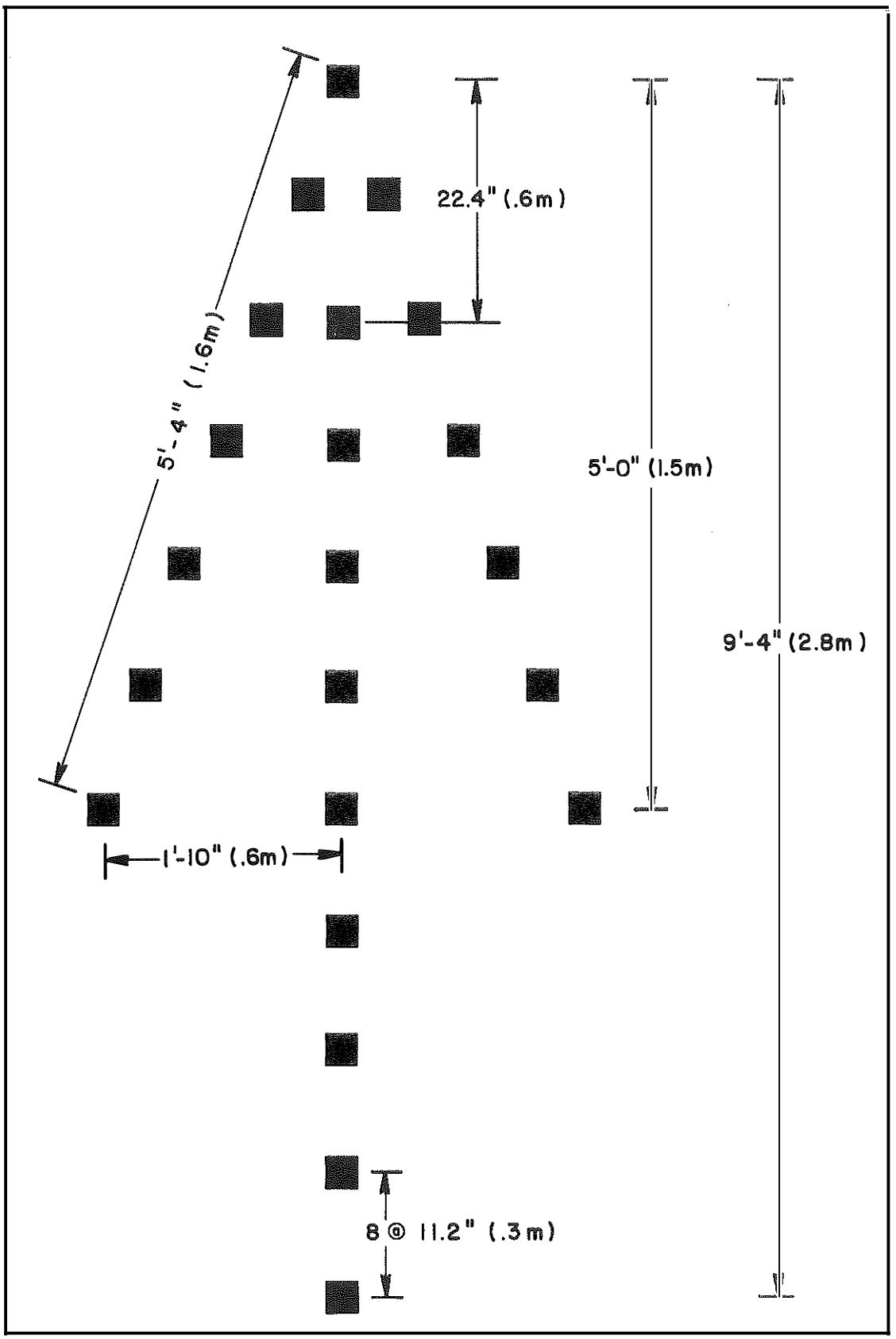


Figure 18. Layout of Directional Arrow.

Figure 19. Daytime Photograph of Directional Arrow Installation.

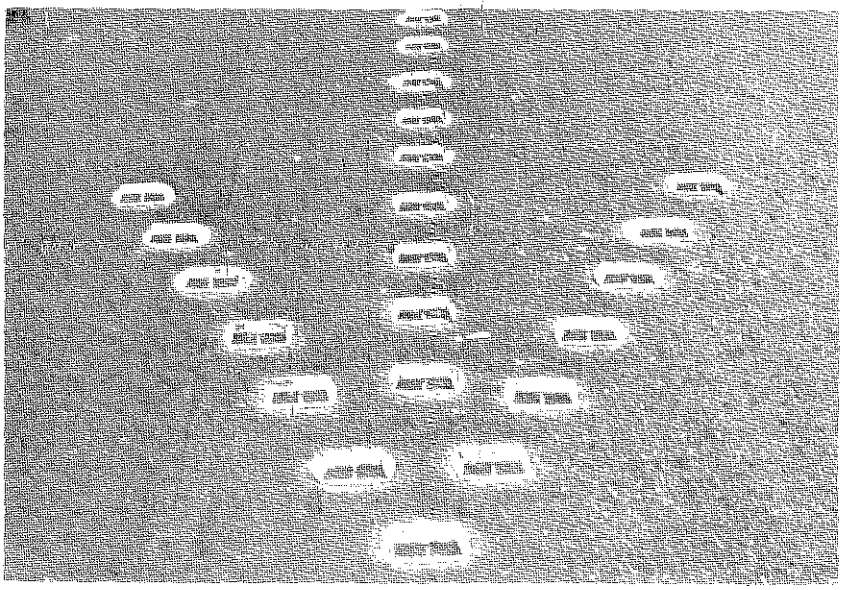


Figure 20. Nighttime Photograph of Directional Arrow Installation.

TABLE 3. COST OF RAISED PAVEMENT MARKERS

BRAND NAME		COST PER MARKER[a]	
Permark P-15		Nonreflective - $0.22 Monodirectional - $0.50 Bidirectional - $0.705	
Stimsonite and Ray-O-Lite	Quantity	Bidirectional	Monodirectional
	1-99	$1.20	$1.10
	100-499	1.14	1.045
	500-999	1.08	0.99
	1000-4999	1.02	0.935
	5000 or more	0.96	0.88
Little Jewel[b]		Monodirectional - $0.60 Bidirectional - $0.68	
Safety Guide[b]		Monodirectional - $0.75 Bidirectional - $0.90	
PD-50 (3M)	List - $0.673	Quantity	Discount
		200-1600	List
		1800-3200	5%
		3400-4800	10%
		5000 and over	15%

[a]All costs are for markers with silver-white reflective lens systems and white marker base (the 3M marker is an exception) and does not include installation costs.

[b]No definite price list was published.

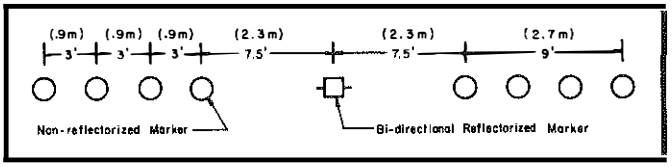


Figure 21. California System of Lane-Line Marking.

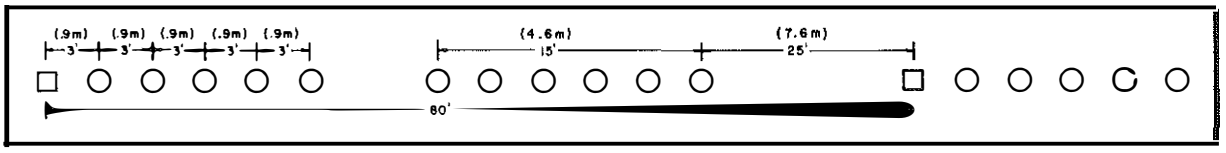


Figure 22. Washington State System of Lane-Line Marking.

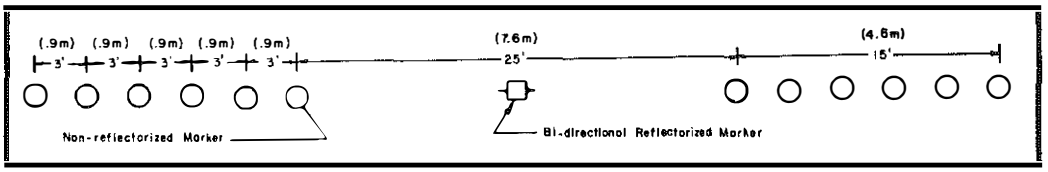


Figure 23. Texas System of Lane-Line Marking.

Louisiana conducted studies of various designs of lane-line markings and concluded that, in areas of low ambient light levels, one reflectorized marker in a stripe of five markers as shown in Figure 24 would be adequate *(8)*. The lane-line design consists of four, non-reflectorized markers with a single, two-way reflectorized marker in the middle of the group. It was their opinion that in urban areas where ambient lighting levels on the roadway were not exceptionally high, the addition of one more reflectorized marker to the lane line would be adequate. In this system, there would be one reflectorized marker at each end of the stripe and three non-reflectorized markers in between. It was also concluded that all five markers should be reflectorized in areas of very high ambient lighting.

From the data presented on durability, it was evident that there will be some loss of reflectorized markers. If the spacing between reflectorized markers is too large, the loss of even one reflector could be very conspicuous and damaging to the delineation system. Therefore, a spacing of 40 feet (12 meters) between reflectorized markers is suggested as a maximum where raised markers replace lane lines. Also, areas with high ambient light levels would require a large number of reflectorized markers to provide sufficient contrast. For these reasons, the system of lane-line marking shown in Figure 25 is recommended for use in Kentucky (areas without high ambient light levels). This system was selected after several trial layouts were observed. APPENDIX D contains pictures and diagrams of the various systems. The system would involve five white markers spaced 3 3/4 feet (1.1 meters) apart to represent the the stripe. Four of these markers would be non-reflective (Type I) while the last marker would be reflectorized (Type II). A highly reflectorized marker (Type III) would be placed 3 3/4 feet (1.1 meter) in advance of the simulated paint stripe. The Type III marker should be placed at the head of a line instead of centered in the gap between lines; this would allow installation in the gap between existing painted lines and allow painted stripes to be renewed if desired. Also, placement of the markers in this manner gives a better representation of a paint stripe. The combination of the Type II and III markers in the simulated stripe provides a safety factor without a large increase in cost. The cost of the markers for the proposed system is $298 per mile (1.6 kilometers) in one direction as compared to a cost of $261 per mile (1.6 kilometers) if all five markers in the stripe were non-reflectorized. It appears that the increase of $37 per mile (1.6 kilometers) can be justified.

Areas with high ambient light levels require more reflectorized markers than areas with low ambient light levels. Therefore, in those areas with high ambient light levels, it is recommended that the number of Type II markers be increased from one to two. The second and fourth white markers would be Type II. The cost of the markers, at current prices, would be $335 per mile (1.6 kilometers). The layout of this system is presented in Figure 26, and Figure D 13 is a nighttime photograph of the system.

An added feature would be the addition of bi-directional markers (silver white and red) to warn wrong-way drivers. The additional cost of alternating Type III markers between mono-directional and bi-directional (spacing of 80 feet (24 meters) between bi-directional markers) would be $26 per mile (1.6 kilometers).

LANE-LINE SUPPLEMENT

Raised markers can be an effective means of supplementing painted lane lines to provide additional delineation, particularly during rainy conditions. After viewing the systems shown in APPENDIX D, it is recommended that a layout consisting of a Type III marker on 80-foot (24-meter) centers be used in areas with low ambient lighting levels and on 40-foot (12-meter) centers in areas with high ambient lighting. Also, in areas with very high traffic volumes, the spacing should be 40 feet (12 meters).

IMPLEMENTATION

Raised pavement markers have proven to be a very effective method of delineation, particularly under wet, nighttime conditions. Therefore, it is recommended that they be used to supplement or replace lane lines in areas with high traffic volumes or high speeds. Also, their use should be considered at high-accident locations such as at hazardous curves. Use of markers as pavement arrows is encouraged. The proposed specifications provide a means of controlling the quality of raised markers as well as insuring their proper usage. The proposed systems of lane-line marking provides a safe means of replacing or supplementing paint stripes.

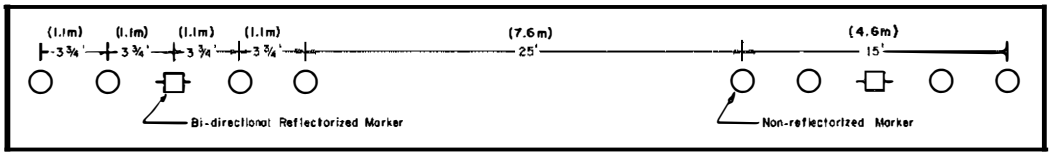


Figure 24. **Louisiana Test System of Lane-Line Marking in Areas with Low Ambient Light Levels.**

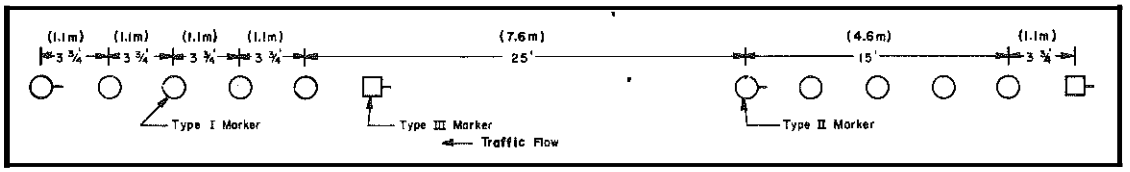


Figure 25. **Proposed Kentucky System of Lane-Line Marking (Areas without High Ambient Light Levels).**

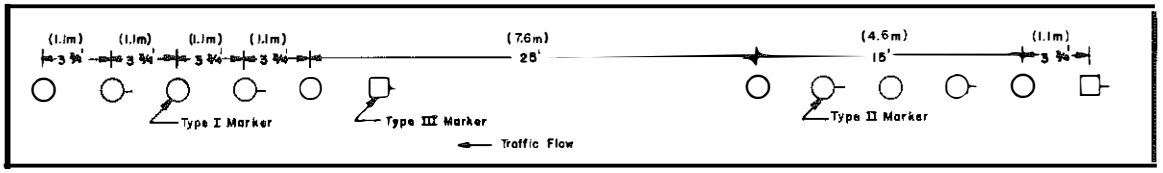


Figure 26. **Proposed Kentucky System of Lane-Line Marking (Areas with High Ambient Light Levels).**

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1. Taylor, J. I; McGee, H. W.; Sequin, E. L.; and Hostetter, R. S. *Roadway Delineation Systems,* **National Cooperative Highway Research Program Report 130,** Highway Research Board, 1972.
2. Pigman, J. G. and Agent, K. R., *Raised Pavement Markers as a Traffic Control Measure at Lane Drops,* Division of Research, Kentucky Bureau of Highways, February 1974.
3. **Instructional Memorandum 21-3-72,** U.S. Department of Transportation, Federal Highway Administration, June 22, 1972.
4. Anderson, D. R., *Rubber Snowplow Blades and Lightweight Snowplows Used for the Protection of Raised Lane Markers,* **Record Number 359,** Highway Research Board, 1971.
5. *Reflective Traffic Bead Study,* Colorado Division of Highways, May 1970.
6. Rizenbergs, R. L., *Development of Specifications for Reflex-Reflective Materials,* Division of Research, Kentucky Department of Highways, October 1970.
7. **Manual on Uniform Traffic Control Devices,** U.S. Department of Transportation, Federal Highway Administration, 1971.
8. Gullatt, S.P. and Calhoun, J.D., *Highway Lane Marking with Reflective Materials,* Louisiana Department of Highways, Mary 1970.

APPENDIX A

DESCRIPTION OF RAISED MARKER INSTALLATIONS

RAISED PAVEMENT MARKER INSTALLATIONS

LOCATION	TYPE MARKER USED	NUMBER USED
	LANE-LINE SUPPLEMENTS	
US 27, South Limestone	Stimsonite	31
	Safety Guide	36
	Permark	31
	Ray-O-Lite (Regular)	27
	Ray-O-Lite (Replaceable Lens)	31
	PD-50 (3M)	37
US 27, Fayette Mall	Stimsonite	72
	Safety Guide	56
	Permark	67
	Ray-O-Lite (Regular)	10
	Ray-O-Lite (Replaceable Lens)	10
	Roadways	4
	PD-50 (3M)	10
US 27, Upper Street	PD-50 (3M)	26
US 60, Versailles Road	PD-50 (3M)	66
	LANE-DROP LOCATIONS	
US 27-68 (Paris Pike) northbound	Safety Guide	41
I 75 northbound-5th Street exit in Covington	Stimsonite	79
I 75 southbound - I 71 southbound in Boone County	Permark	63
I 75 northbound - I 64 eastbound east of Lexington	Ray-O-Lite (Regular)	61
I 75 southbound - I 64 eastbound east of Lexington	Ray-O-Lite (Replaceable Lens)	57
I 75 - I 64, east of Lexington	Stimsonite	32
I 75 northbound, north of Lexington	PD-50 (3M)	33
	HAZARDOUS CURVE LOCATIONS	
I 75 southbound at I 64, north of Lexington	Stimsonite	79
US 60 (Winchester Road) at KY 4, east of Lexington	Permark	33
US 60 (Versailles Road) at El Dorado Motel, west of Lexington	Stimsonite	25
	PAVEMENT ARROWS	
I 75 northbound exit ramp onto US 27-68 (North Broadway)	Stimsonite	23
I 75 southbound exit ramp onto US 27-68 (North Broadway)	Permark	22
I 64 eastbound exit ramp onto US 127, south of Frankfort	Stimsonite	22
I 64 eastbound exit ramp onto KY 55, west of Shelbyville	Ray-O-Lite (Regular)	22
KY 4 westbound exit ramp onto KY 1681 (Old Frankfort Pike) north of Lexington	Ray-O-Lite (Regular)	22
KY 4 eastbound exit ramp onto KY 1681 (old Frankfort Pike) north of Lexington	Permark	22

APPENDIX B

PHOTOGRAPHS OF RAISED MARKER INSTALLATIONS

Figure B1. Safety Guide Markers at Fayette Mall (Dry, Daytime).

Figure B2. Ray-O-Lite (replaceable lens) Markers on South Limestone Street (Wet, Daytime).

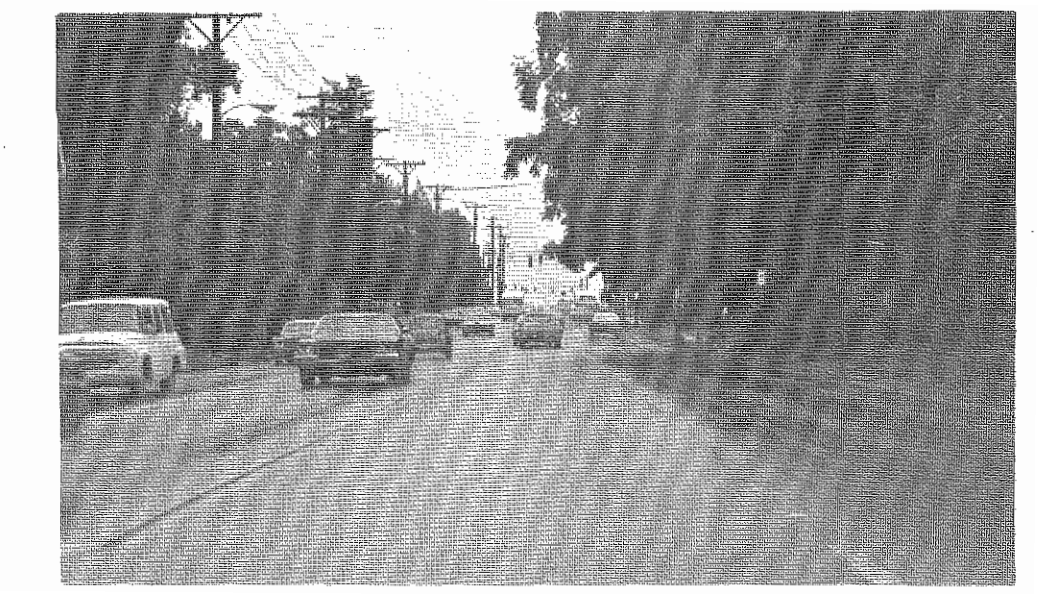
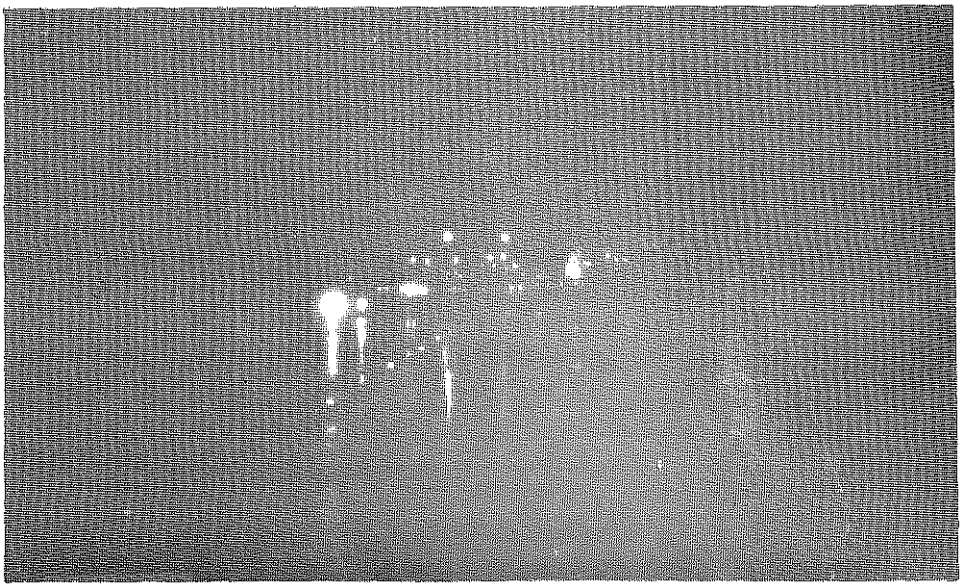


Figure B3. Stimsonite and Ray-O-Lite (regular) Markers at Fayette Mall (Wet, Nighttime).



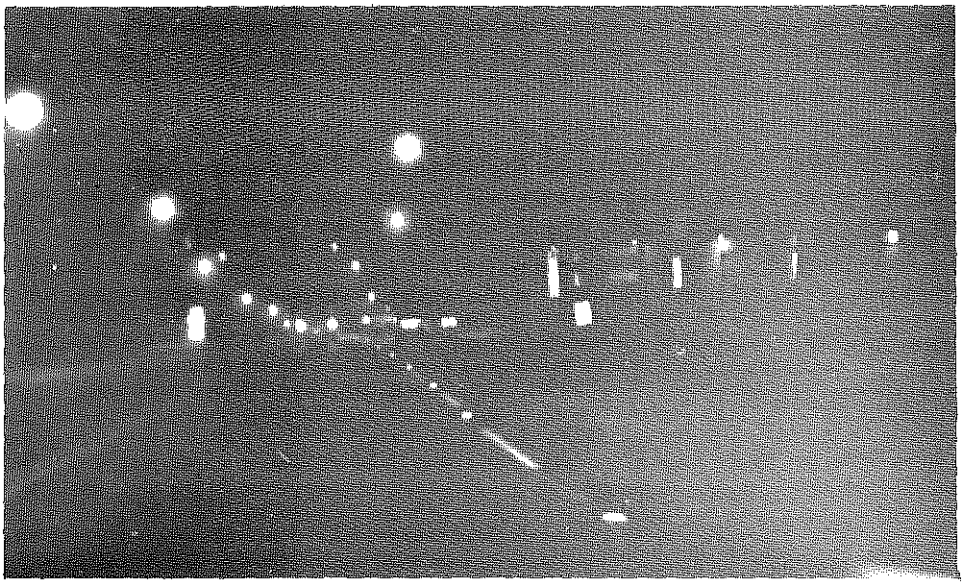


Figure B4. Ray-O-Lite (regular) Markers on South Limestone Street (Dry, Nighttime).

APPENDIX C

PROPOSED SPECIFICATIONS FOR RAISED PAVEMENT MARKERS

KENTUCKY DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
SPECIAL PROVISION NO. XXX
REFLECTORIZED AND NON-REFLECTORIZED RAISED PAVEMENT MARKERS

This Special Provision shall apply when specified in plans, proposals, or invitations for bids.

I. DESCRIPTION

This work shall consist of furnishing and installing raised pavement markers at locations shown on the plans and as directed by the engineer.

Raised markers shall conform to the requirements for Type I, Type II, or Type III markers as designated on plans or proposals and described as follows:

Type I - Non-reflectorized marker
Type II - Reflectorized marker
Type III - Highly reflectorized marker

Markers shall be tested and approved in lots by the Department before installation.

Unless otherwise specified or approved in writing by the engineer, one brand of markers will be used throughout the project for each type of marker required.

The reflectorized markers may be reflectorized mono-directional or bi-directional, as specified in the plans. The plans will also specify the color of the lens.

II. REQUIREMENTS

Markers will be classified as Type I, Type II, or Type III and shall conform to the applicable requirements for the particular type of marker.

A. **Type I Markers:** Type I markers shall be non-reflectorized and shall consist of a heat-fired, white, ceramic base and a heat-fired, opaque, glazed surface to produce the properties required in these specifications. The glazing shall not be present on the bottom surface which will be cemented to the road surface. The markers shall be thoroughly and evenly annealed and free from defects which affect appearance or serviceability. The markers shall meet the following requirements:

1. *Dimensions:* The top surface of the marker shall be convex, and the radius of curvature shall be between 3-1/2 inches and 6 inches; the radius of the 1/2 inch nearest the edge may be less. Any change in curvature shall be gradual.
2. *Dimensions:* Each marker shall be 4 ± 0.1 inches in diameter at the base. Height of the marker shall be 11/16 ± 1/16 inch. The base of the marker shall not deviate from a flat plane by more than 1/16 inch.
3. *Glaze Thickness:* The glazed surface shall have a mean thickness not less than 0.005 inch when measured not closer than 1/4 inch from the edge of the marker.
4. *Water Absorption:* The water absorption of the ceramic marker shall not exceed 2.0 percent of the original dry weight when tested in accordance with ASTM C-373.
5. *Autoclave Test:* The glazed surface of the marker shall not craze, spall, or peel when subjected to one cycle of the autoclave test at a pressure of 250 pounds per per square inch (ASTM C 424).
6. *Load Resistance:* The average load resistance of any five buttons shall not be less than 1500 pounds, and no individual marker shall have a load resistance less than 1200 pounds when tested as follows. The marker shall be centered, base down, over the open end of a vertically-positioned hollow metal cylinder. The cylinder shall be 1 inch high and have an internal diameter of 3 inches and a wall thickness of 1/4 inch. A load necessary to break the marker shall be applied at a rate of deformation of 0.2 inch per minute to the top of the marker through a 1-inch diameter, solid metal cylinder centered on the top of the marker.
7. *Surface Color:* Color of glazed surfaces shall be white or yellow as specificed in the plans or proposals. The yellow surfaces shall conform to the Color Tolerance Charts issued by the Federal Highway Administration and referred to as Highway Yellow (PR Color #1). White markers shall be white or near-white.

B. **Type II Markers:** Type II markers shall be further classified as Type II-A, Type II-B, and Type II-C. The Type II-A markers shall consist of a ceramic dome base with a glazed surface. The base of the marker shall be textured and free from gloss, glaze, or substances that may reduce its bond to the adhesive. An acrylic rod-reflex reflector system shall be inset and cemented into a revetment formed into the base. The Type II-A markers shall meet the following requirements:

1. *Dimensions:* The base of the marker shall be 4 ± .1 inches in diameter and approximately 3/4 inch in height.
2. *Reflective Lens:* 1 3/4 inches in length, horizontally.

3. *Glaze Thickness:* Thickness of the glazed surface shall not be less than 0.005 inch when measured not closer than 1/4 inch from the edge of the marker.
4. *Water Absorption:* The water absorption of the ceramic marker shall not exceed 2.0 percent of the original dry weight when tested in accordance with ASTM C-373.
5. *Autoclave Test:* The glazed surface of the marker shall not craze, spall, or peel when subjected to one cycle of the autoclave test at a pressure of 250 pounds per square inch (ASTM C 424).
6. *Load Resistance:* The average load resistance of any five markers shall not be less than 1500 pounds, and no individual marker shall have a load resistance less than 1200 pounds when tested as follows. The marker shall be centered, base down, over the open end of a vertically-positioned hollow metal cylinder. The cylinder shall be 1 inch high and have an internal diameter of 3 inches and a wall thickness of 1/4 inch. A load necessary to break the marker shall be applied at a rate of deformation of 0.2 inch per minute to the top of the marker through a 1-inch diameter solid metal cylinder centered on the top of the marker.
7 *Surface Color:* Color of glazed surfaces shall be white, yellow, or red or a combination of white and red as specified in the plans or proposals. The yellow surfaces shall conform to the Color Tolerance Chart issued by the Federal Highway Administration and referred to as Highway Yellow (PR Color #1). The red surfaces shall conform to Highway Red (PR Color #2). White markers shall be white or near-white.

Type II-B markers shall consist of an acrylonitrile-butadiene-styrene (ABS) body having the dimensions of 4 x 4 x 0.625 inches and a reflective strip consisting of ten glass beads recessed in the marker face. The underside of the marker shall be waffle-textured.

Type II-C markers shall consist of an acrylonitrile-butadiene-styrene (ABS) circular body having a diameter of 4 inches and a thickness of 3/4 inch; a prismatic lens system shall be recessed in the marker face. The bottom of the markers shall have eight ridges.

Type II-B and Type II-C markers shall also meet the following requirements:

1. *Surface Color:* Color of the markers shall be white or yellow as specified in the plans or proposals. The yellow surfaces shall conform to the Color Tolerance Chart issued by the Federal Highway Administration and referred to as Highway Yellow (PR Color #1). White markers shall be white or near-white.
2. *Heat Resistance:* The marker shall show no significant change in shape or general appearance when subjected to the following heat test. The marker shall be placed in a vertical position in a circulating air oven set at 140 F. After four hours, the unit shall be removed from the oven and permitted to cool in air to room temperature. The unit shall then be compared to corresponding, unexposed units.
3. *Impact Resistance:* The marker shall not break, chip, or crack when subjected to the impact of a steel ball, 1 7/8 inches in diameter, falling freely from a height of 2 feet. Impact tests shall be performed at room temperature (70 F to 80 F). The marker shall rest, topside up, on a steel plate not less than 1/2 inch thick. The marker shall not be held or restrained in any manner. The steel ball shall strike at the approximate center of the marker.

The specific reflectivity of Type II markers at 0.2° divergence angle, when tested in accordance with the methods in the current edition of Special Provision No. 89, shall be as follows when the incident light is parallel to the base of the marker:

Minimum Specific Reflectivity
(candlepower/footcandle/unit marker)

	Incidence Angle	
Color	0°	20°
Silver-white	0.70	0.25
Amber	0.45	0.17
Red	0.15	0.07

C. **Type III Markers.** Type III markers shall be highly reflectorized for nighttime visibility. The markers shall contain prismatic reflectors viewable from a single or opposite direction as specified in the plans or proposals. Type III markers shall be further classified as Type III-A and Type III-B.

Type III-A markers shall consist of an acrylic plastic shell filled with a tightly adherent potting compound. The shell shall be molded of methyl methacrylate conforming to Federal Specification L-P-380a, Type I, Class 3. The filler shall be a potting compound selected for strength, resilience, and adhesion.

Type III-B markers shall consist of an acrylonitrile-butadiene-styrene (ABS) shell filled with an inert, thermosetting compound and filler. The lens portion of the marker shall be made of optical methyl metharcylate.

Type III markers shall meet the following requirements:

1. *Dimensions:* Each marker shall be 4 x 4 inches at the base. Heights of the marker shall be 0.65 inch or no higher than 0.75 inch after preparation of the base of the marker for bonding.
2. *Outer Surface:* The outer surface of the shell shall be smooth except for purposes of identification.
3. *Base Surface:* The base of the marker shall be substantially free from gloss or substances that may reduce its bond to adhesive.
4. *Load Resistance:* The markers shall support a load of 2,000 pounds when applied in the following manner: A marker shall be centered over the open end of a vertically-positioned hollow metal cylinder. The cylinder shall be 1 inch in height and have an internal diameter of 3 inches and a wall thickness of 1/4 inch. Load shall be applied slowly to the top of the marker through a 1-inch diameter by 1-inch high metal rod centered on the top of the marker. Failure shall constitute either breakage or significant deformation of the marker at any load less than 2,000 pounds.
5. *Reflectivity:* The specific reflectivity of the reflective surface at 0.2° divergence angle, when tested in accordance with the methods in the current edition of Special Provision No. 89, shall be as follows when the incident light is parallel to the base of the marker:

Minimum Specific Reflectivity
(candlepower/footcandle/unit marker)

Color	Incidence Angle 0°	Incidence Angle 20°
Silver-white	2.7	0.9
Amber	1.8	0.6
Red	0.5	0.22

III. CONSTRUCTION METHODS

The Type I, Type II, and Type III markers shall be cemented to the pavement with adhesive recommended and furnished by the manufacturer of the marker.

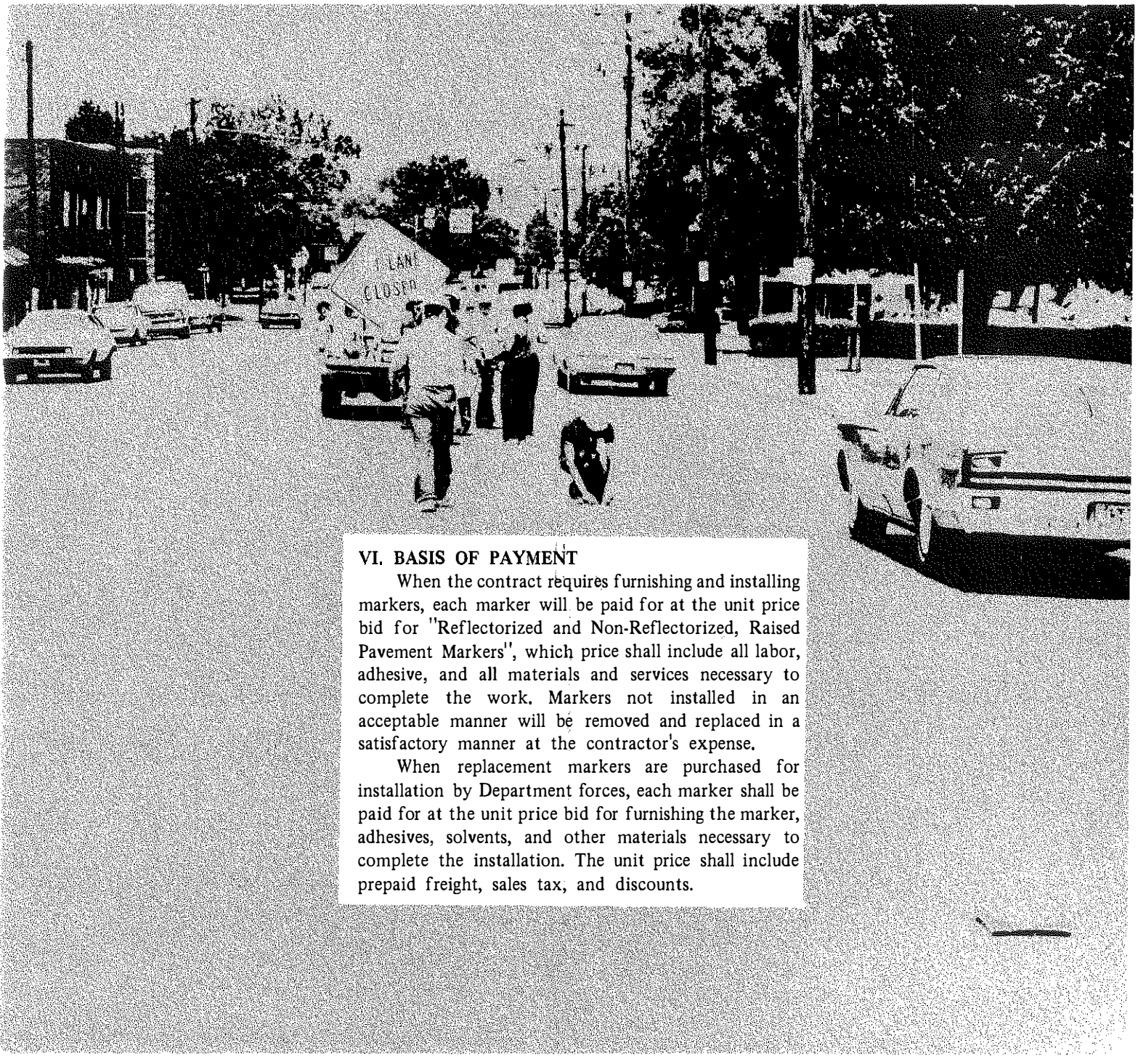
The pavement surfaces shall be prepared and the markers installed according to the manufacturer's recommendations and the following requirements. The portion of the pavement surface to which the marker is to be cemented shall be cleaned of dirt, grease, oil, loose or unsound layers, and any other material which would reduce the bond of the adhesive. Cleaning shall be done by blast cleaning or other approved methods. Pavement surfaces shall be maintained in a clean condition until markers are placed. The adhesive bed area shall be equal to the bottom area of the marker, and adhesive shall be applied in sufficient quantity to cause excess to be forced out around the entire perimeter of the marker. Voids in markers with an open grid pattern on the bottom shall be filled with adhesive during placement.

IV. SAMPLING

For the purpose of sampling, a shipment shall consist of the amount of material received in one delivery even though it may represent only partial delivery of the contracted quantities. Samplings shall be made from at least five widely separated and indiscriminately chosen packages of like materials included in the shipment. Samples shall be submitted for reflectivity, color, and other testing deemed necessary.

V. PACKAGING

All materials shall be suitably and substantially packaged and shall have the name and address of the manufacturer or vendor, contract or purchase order number, kind of material, trade name, and net contents plainly marked on each package.



VI. BASIS OF PAYMENT

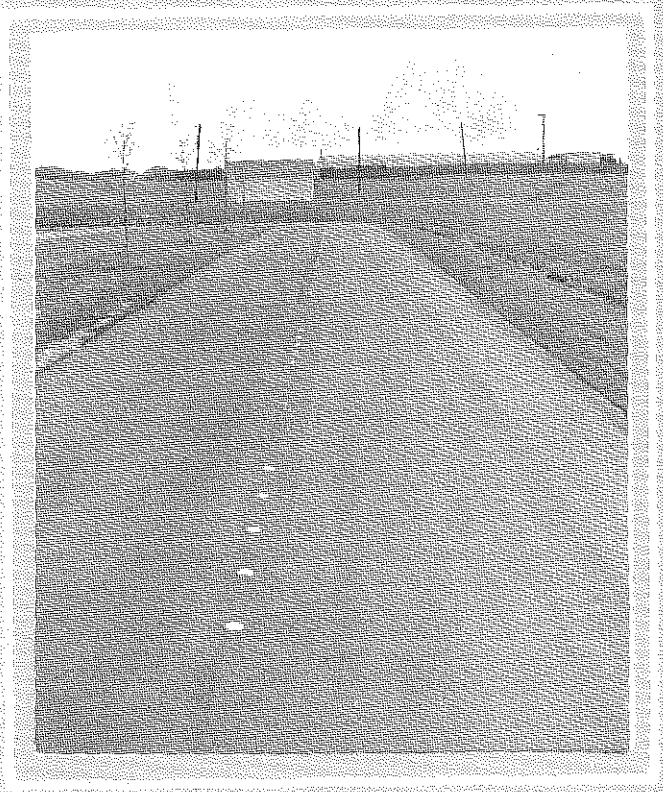
When the contract requires furnishing and installing markers, each marker will be paid for at the unit price bid for "Reflectorized and Non-Reflectorized, Raised Pavement Markers", which price shall include all labor, adhesive, and all materials and services necessary to complete the work. Markers not installed in an acceptable manner will be removed and replaced in a satisfactory manner at the contractor's expense.

When replacement markers are purchased for installation by Department forces, each marker shall be paid for at the unit price bid for furnishing the marker, adhesives, solvents, and other materials necessary to complete the installation. The unit price shall include prepaid freight, sales tax, and discounts.

APPENDIX D

TRIAL RAISED MARKER LAYOUTS

Figure D1. Five Permark Markers (Kentucky Type I) per Lane Line.



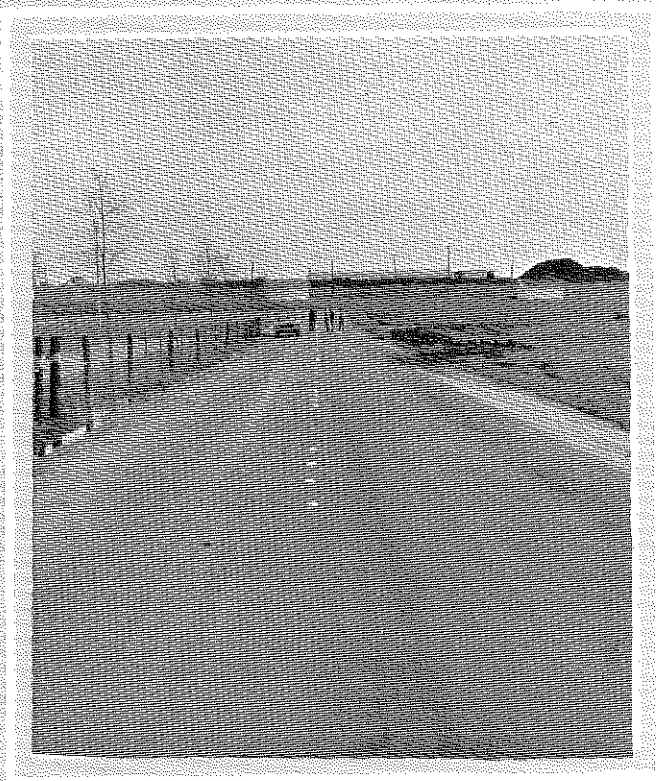


Figure D2. Four Permark Markers (Kentucky Type I) per Lane Line.

Figure D3. Six Permark Markers (Kentucky Type I) per Lane Line.

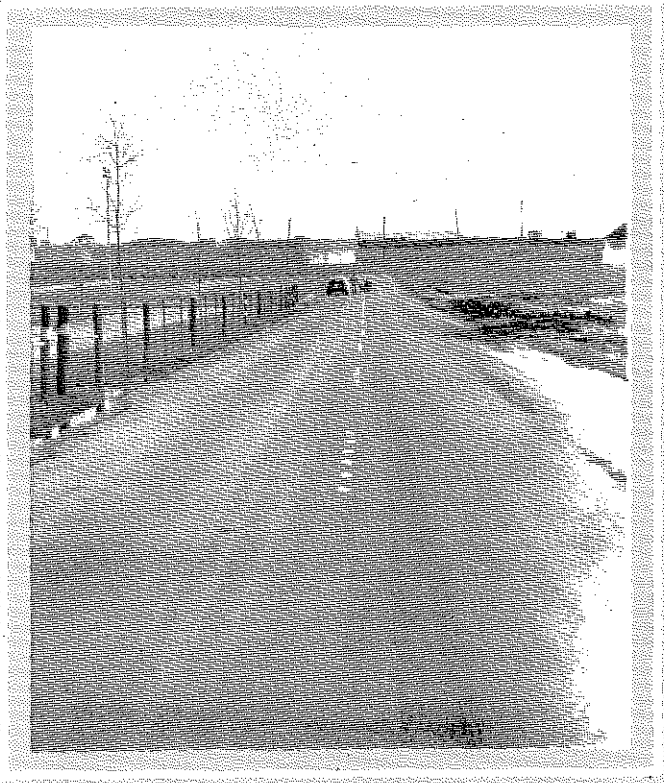


Figure D4. Stimsonite Markers at 40-Foot (12-meter) Spacing.

Figure D5. Stimsonite Markers at 80-Foot (24-meter) Spacing.

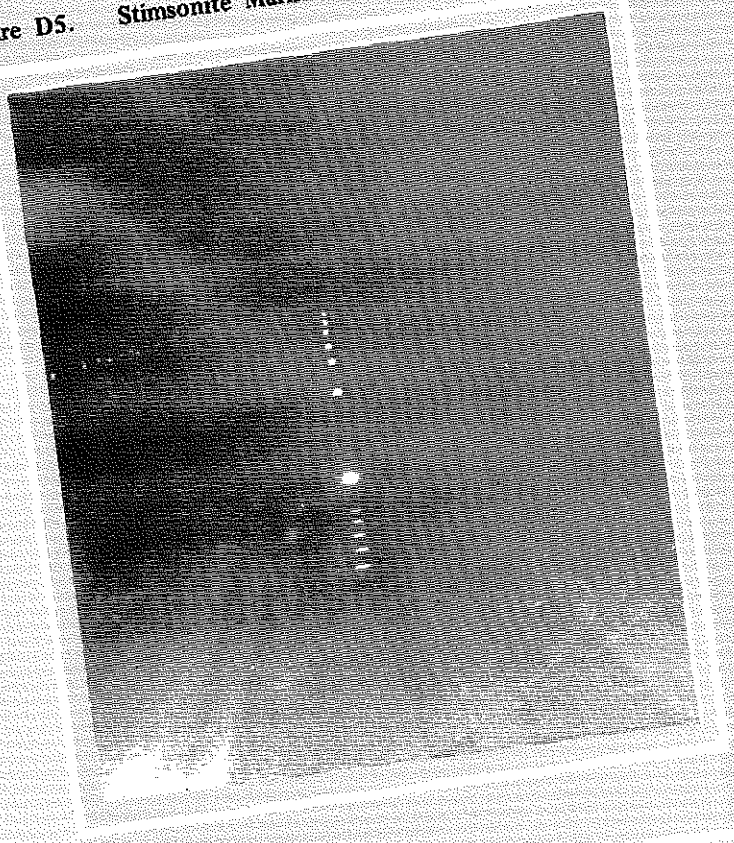


Figure D6. Stimsonite Markers at 20-Foot (6-meter) Spacing.

Figure D7. Alternating Permark and Stimsonite Reflective Markers at 40-Foot (12-meter) Spacing.

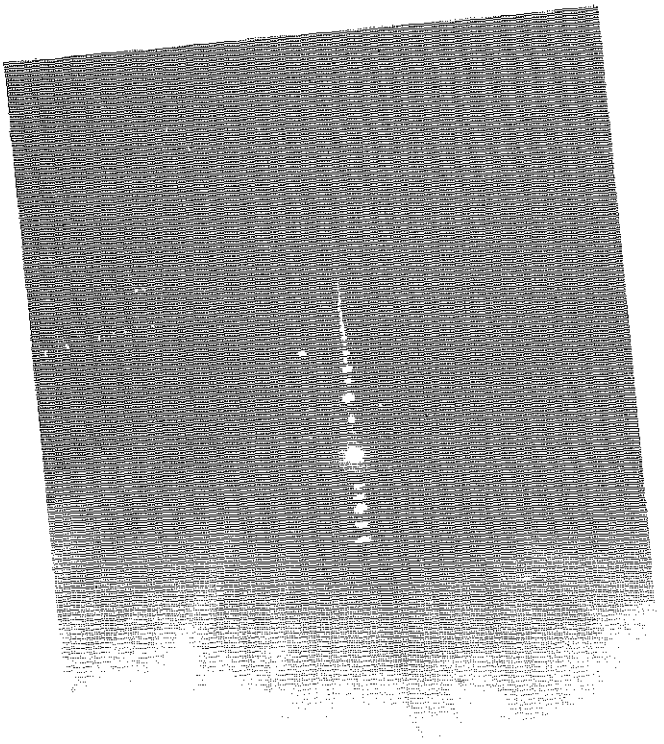
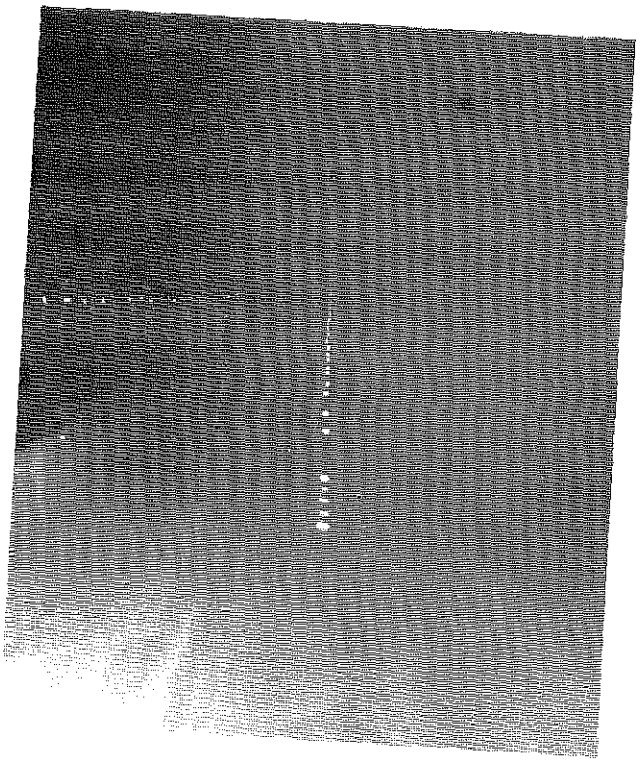


Figure D8. Stimsonite (80-foot (24-meter) spacing) and Permark (40-Foot (12-meter) Spacing) Markers.

Figure D9. Permark Markers at 40-Foot (12-meter) Spacing.

Figure D10. Three Permark (Kentucky Type II) Markers per Lane Line.

Figure D11. Two Permark (Kentucky Type II) Markers per Lane Line.



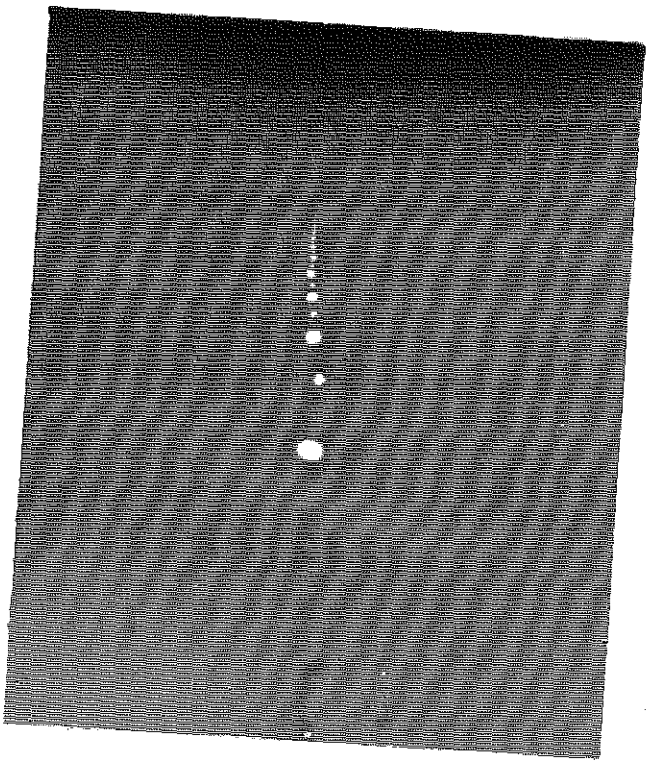
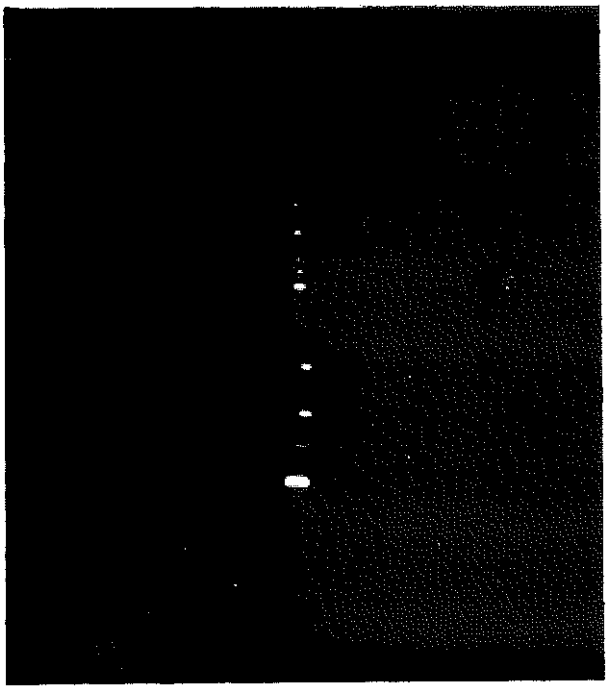


Figure D12. One Stimsonite Followed by One Permark (Kentucky Type II) Marker per Lane Line (Proposed Kentucky System Lane-Line Marking in Areas without High Ambient Lighting).

Figure D13. One Stimsonite Followed by Two Permark (Kentucky Type II) Markers per Lane Line (Proposed Kentucky System of Lane-Line Marking in Areas with High Ambient Lighting).



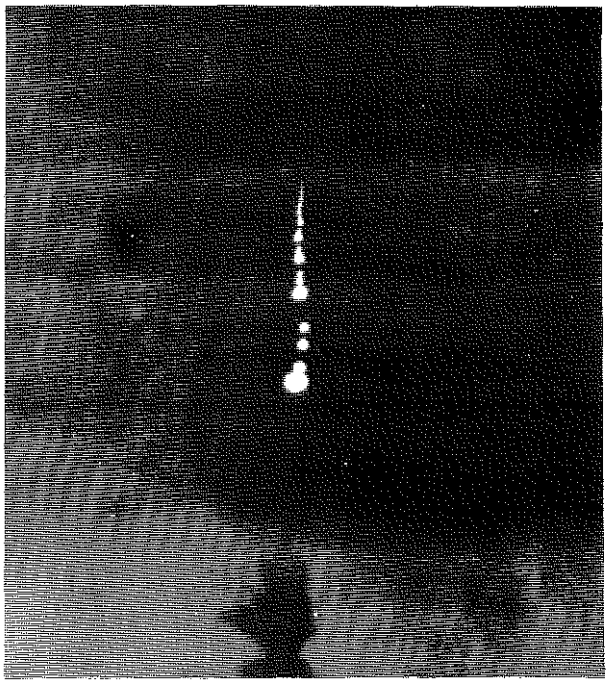
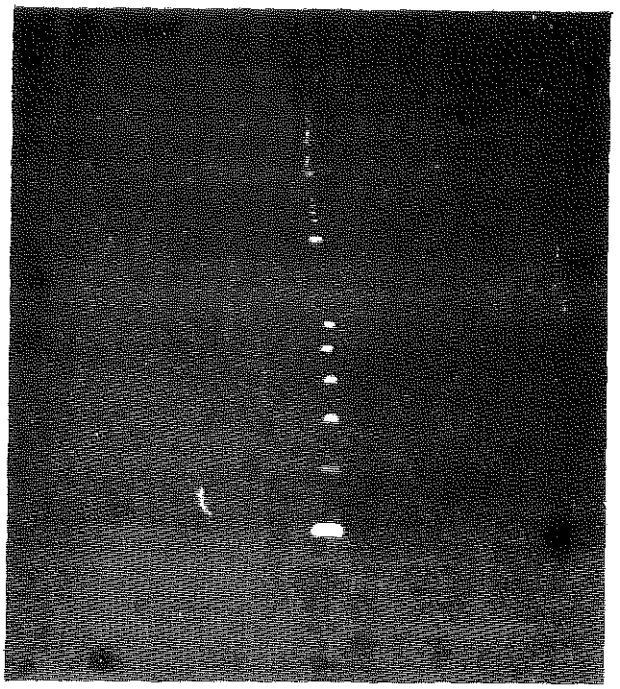


Figure D14. One Stimsonite Followed by Three Permark (Kentucky Type II) Markers per Lane Line.

Figure D15. One Stimsonite Followed by Four Permark (Kentucky Type II) Markers per Lane Line.



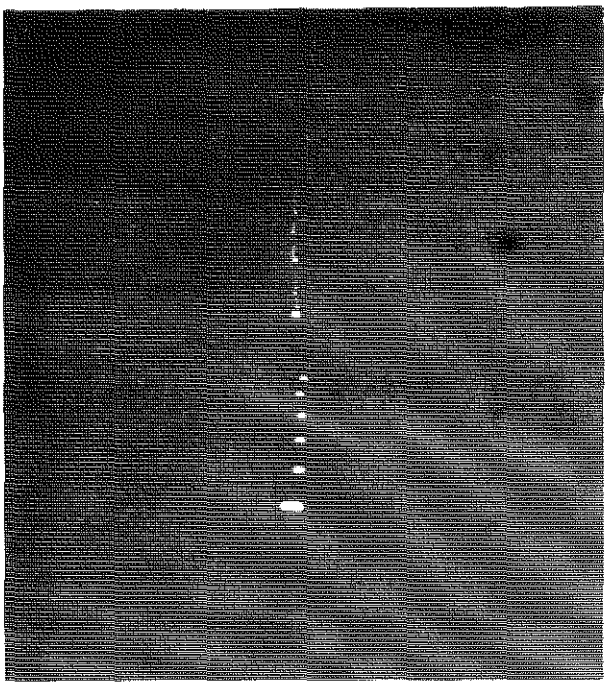


Figure D16. One Stimsonite Followed by Five Permark (Kentucky Type II) Markers per Lane Line.

Figure D17. Daytime Photograph of Proposed Kentucky System of Lane-Line Markings in Areas without High Ambient Light Levels. One Kentucky Type III Marker, Four Kentucky Type I Markers, Followed by One Kentucky Type II Marker.

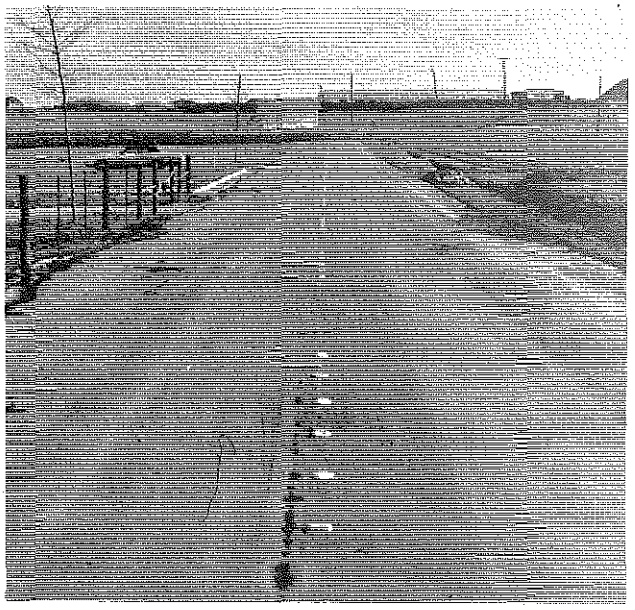


Figure D18. Daytime Photograph of Proposed Kentucky System of Lane-Line Markings in Areas with High Ambient Light Levels. First Is One Kentucky Type III Marker; Second, Fourth, and Sixth Are Kentucky Type I; Third and Fifth Are Kentucky Type II.